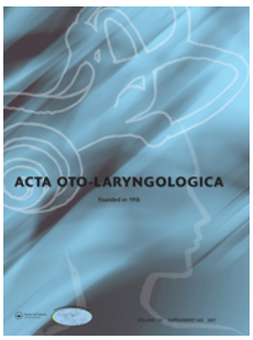

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RESEARCH ARTICLE

Differences between acoustic trauma and other types of acute noise-induced hearing loss in terms of treatment and hearing prognosis

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ABSTRACT

Objectives: To evaluate the differences between acoustic trauma (AT) and other types of acute noise-induced hearing loss (ANIHL), we performed a literature search and case reviews.

Methods: The literature search based on online databases was completed in September 2016. Articles on ANIHL and steroid treatment for human subjects were reviewed. The source sounds and treatment sequelae of our accumulated cases were also reviewed. Hearing loss caused by gun-shots and explosions was categorized into the AT group, while hearing loss caused by concerts and other noises was categorized into the ANIHL group.

Results: Systemic steroid treatment did not appear to be effective, at least in the AT group, based on both the literature and our case reviews. However, effective recovery after treatment including steroids was observed in the ANIHL group. The difference in hearing recovery between the AT and ANIHL groups was statistically significant ($p = .030$), although differences in age, days from the onset to treatment and pretreatment hearing levels were not significant.

Conclusions: Hearing recovery from AT is very poor, whereas, ANIHL is recoverable to some extent. Therefore, it is essential to differentiate between these two groups for accurate prediction of the hearing prognosis and evaluation of treatment effects.

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Noise-induced hearing loss; acoustic trauma; acoustic ear injury; noise exposure; threshold shift; hearing recovery; treatment; steroids

Introduction

Loud sound is one of the major causes of hearing loss [1]. Such hearing damage takes various forms from acute to chronic. Although 'acoustic trauma' can sometimes be regarded as roughly equivalent to noise-induced hearing damage, including chronic cases, the clinical courses and therapeutic responses of those types of hearing loss differ markedly.

Noise-induced hearing loss can be divided into acute and chronic types (Table 1). Chronic noise-induced hearing loss is further divided into occupational and non-occupational types. The majority of chronic noise-induced hearing loss is occupational, therapeutic intervention for which has been limited to date.

Acute noise-induced hearing loss (ANIHL) can also be divided into two categories. One is acoustic trauma (AT) and the other is ANIHL, such as concert-related hearing loss. AT is caused instantaneously, for example, by a single gun-shot or firecracker explosion. Immediately on exposure, mechanical injury is induced because the noise level physically exceeds the 'elastic limit' of the peripheral auditory mechanism [2]. This type of injury is caused by an extremely intense noise level (≧130 dBA). On the other hand, ANIHL is usually caused after a certain exposure time, ranging from several minutes to several hours. Concert-goers often notice ringing sounds or muffled ears after attending such events. This type of hearing damage is caused mainly by metabolic injury due to 'excitotoxicity' [3] through exposure to intense sound of around 100–120 dBA.

Acute noise-induced hearing losses are presumed to be reversible to some extent. Several treatments are currently used

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Table 1. Noise-induced hearing damage.

Classification	Typical causes of exposure	Duration of exposure
Acute noise-induced hearing loss		
Acoustic trauma (AT)	Gun-shot Firecracker	Instant
Acute noise-induced hearing loss (ANIHL)	Concert Other sources of sound	Usually several minutes to hours
Chronic noise-induced hearing loss		
Occupational noise-induced hearing loss	Long-term noise exposure in occupational settings	5–15 years or more
Non-occupational noise-induced hearing loss	Long-term noise exposure in non-occupational settings	Depends on the case

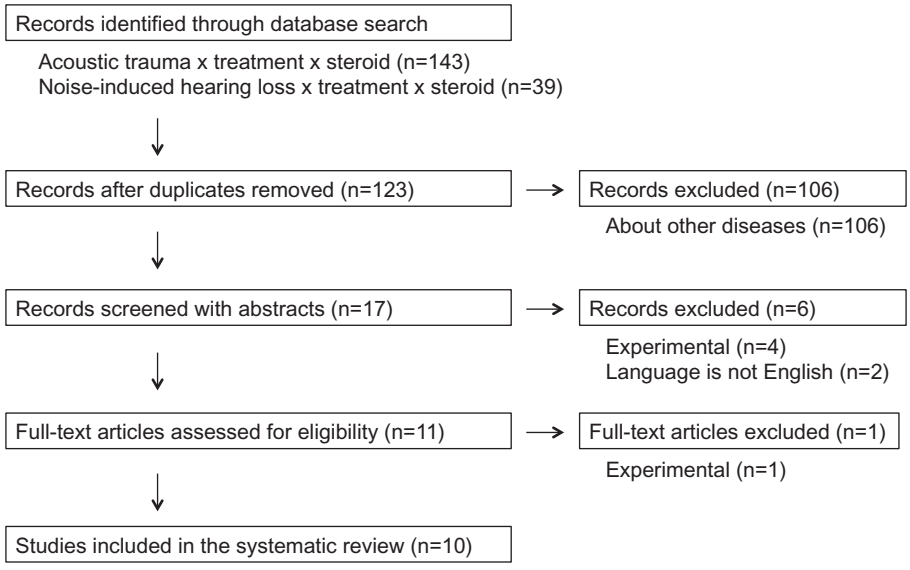

Figure 1. Flow diagram of the inclusion and exclusion of articles.

in clinical practices to facilitate recovery, with steroids [4], hyperbaric oxygen therapy (HBO) [5] and dextran [6] being the most widely used. However, the evidence regarding the effectiveness of such treatments is not particularly convincing, even for the most commonly used 'systemic steroid therapy'.

We reviewed previous literature as well as our cases to elucidate the critical factors affecting hearing recovery and the value of steroid treatment in ANIHL.

Materials and methods

A systematic review of the literature

Search strategy

A systematic review of the published literature dealing with cases of ANIHL and steroid therapy was performed. A search of the PubMed/MEDLINE and EMBASE databases was performed in September 2016, using the search terms, 'acoustic trauma' or 'noise-induced hearing loss', 'treatment' and 'steroid'. Only English language articles limited to human subjects were considered.

Selection criteria

Studies with both individual and aggregated data describing the diagnosis of AT and/or ANIHL, and steroid treatment for patients were included. Exclusion criteria included irrelevant studies (chronic noise-induced hearing loss and other diseases), studies without details of treatment or outcome, animal studies, studies written in languages other than English and articles for which full texts were not obtainable. Two authors (T.W. and H.S.) performed the search review to determine that all appropriate articles were included in the analysis (Figure 1).

Data extraction

Variables collected included author, publication year, subjects and source of sounds, sample size, treatment and conclusions.

Case review

Search strategy

Cases of ANIHL accumulated from the institutions participating in our research were also reviewed. A diagnosis of ANIHL was based on the following criteria.

- *Definite*: cases with sensorineural hearing loss immediately/soon after exposure to loud sound, with other diseases excluded.
- *Probable*: cases with combined hearing loss and similar clinical history to definite cases.
- *Possible*: cases with similar clinical history to definite cases, although perilymph fistula was not excluded.

Table 2. Studies including acute noise-induced hearing damage and steroid treatment.

Author (year)	Subjects and source sounds	No. of ears	Treatment	Conclusion	Ref.
Salihoğlu et al. (2015)	Firearms	73	Steroid + HBO	Success rate was very low. Early initiation of therapy leads to greater gains.	[7]
Zhou et al. (2013)	Fireworks: 42% Military: 39% Music: 9% Others: 10%	53	Local steroid or steroid alone	Early application of transtympanic steroid is effective.	[4]
Lafère et al. (2010)	Military	68	Steroid + HBO or steroid alone	HBO + steroid is more effective than steroid alone.	[5]
Psillas et al. (2008)	Military	52	Steroid + piracetam	Early treatment (within 1 h) improves recovery.	[9]
Harada et al. (2008)	Firearms	24	Steroid, dextran and Vit. B_{12}	Early treatment and 4000 Hz hearing level related to recovery.	[6]
Markou et al. (2004)	Military	146	Steroid, Vit. B, trimetazidine, piracetam	Early treatment (within 1 week) improves tinnitus.	[10]
Cacace et al. (2003)	Rock-music concert	1	Steroid, diuretic, accidental food allergy	Hearing loss persisted after steroid treatment. Rapid recovery of hearing was observed after food-induced anaphylactoid reaction.	[11]
Harada et al. (2001)	Firearms: 49 Firecrackers: 2 Rock music: 1	52	Steroid, dextran and Vit. B_{12}	Days before treatment and initial hearing levels related to outcome. Age, use of ear-plug and drug therapy not related.	[8]
Vavrina and Müller (1995)	Military: 1/3 Other causes not described	78	Steroid, dextran, gingko extract or + HBO	HBO started within three days accelerates hearing recovery.	[12]
Melnick (1984)	Review of acoustic trauma	996	Various combinations of treatment	No treatment method has demonstrated valid or reliable evidence of effectiveness.	[13]

Hearing test

Pure-tone audiometry was used to evaluate hearing level. The average of the hearing levels at 250, 500, 1000, 2000 and 4000 Hz was calculated and compared between the initial and final audiograms.

Statistical analysis

Descriptive statistics were presented as mean ± standard deviation (SD). Differences between the groups were assessed using a one-way analysis of variance (ANOVA). All statistical analyses were performed with the SPSS Statistics 21 (IBM, Armonk, NY). A value of $p < .05$ was considered statistically significant.

This study was approved by each institutional review board of all the attending institutions.

Results

Systematic review of the literature

Our initial PubMed/MEDLINE and EMBASE search identified a total of 143 articles using the search terms, 'acoustic trauma', 'treatment' and 'steroid', and 39 articles using 'noise-induced hearing loss', 'treatment' and 'steroid' (Figure 1). Duplicates and irrelevant reports were removed. A total of 10 articles were included in this review, ranging in publication date from 1984 to 2015, as shown in Table 2. Five of the 10 articles described subjects exposed to firearms or military personnel. Four other articles also included similar subjects. Systemic steroid therapy was used as the standard treatment in nine of the 10 articles.

Case review

Cases

There were 54 cases diagnosed with ANIHL. The cases without a detailed history of noise exposure and treatment were excluded. Those without initial and/or final audiograms were also excluded. In total, 18 cases satisfied the inclusion criteria and were diagnosed as definite cases of ANIHL. Among those 18 cases, nine cases were considered to be AT caused by a gun-shot or explosion. The other nine cases were classified as ANIHL due to concert noise or other loud sounds. Three cases were affected bilaterally; two in the AT group, and one in the ANIHL group (Figure 2).

Although ATP, vitamin B12, kallidinogenase and prostaglandins were used depending on the cases, systemic steroid therapy was most commonly applied (15 of 18 cases) in our cases. In one case, this was followed by treatment with intratympanic steroid injection. Various kinds of steroids were administered; however, the initiating dose in each case was at least 30 mg equivalent of prednisolone. No HBO was applied in our cases.

There was a preponderance of male over female patients, particularly in the AT group (Table 3). The ages were quite

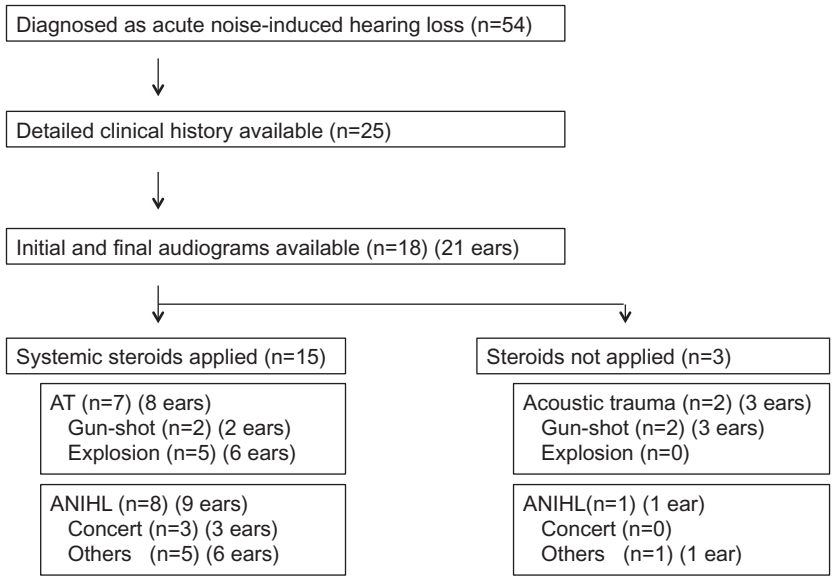

Figure 2. Flow diagram of included and excluded cases. AT: acoustic trauma; ANIHL: acute noise-induced hearing loss.

Table 3. AT vs. ANIHL in 18 cases (21 ears).

Classification	AT ($n = 9$) (11 ears)	ANIHL ($n = 9$) (10 ears)	p Value
Male:female	($n = 9$) 8:1	($n = 9$) 5:4	–
Age	39.4 ± 13.6 (19–61)	39.3 ± 20.4 (13–70)	.990
Exposure to visit (days)	6.1 ± 6.0 (0–20)	3.2 ± 3.2 (0–10)	.247
Average hearing level on initial audiogram	(11 ears) 36.1 ± 16.1 (11–71)	(10 ears) 45.6 ± 33.0 (9–101)	.404
On final audiogram	33.5 ± 13.3 (10–55)	28.4 ± 25.4 (7–76)	.563
Hearing recovery	2.5 ± 4.6 (–1 to 16)	17.2 ± 20.2 (–1 to 61)	.030[a]

[a]Significant difference ($p < 0.05$) (one-way ANOVA).

well matched between the AT and ANIHL groups, and there was no significant difference in the average time from symptom onset to the beginning of treatment between the two groups.

Recovery of hearing

The average hearing levels of the initial or final audiograms did not differ significantly between the two groups. However, the average hearing recovery in the ANIHL group was significantly better than that in the AT group (one-way ANOVA, $p = .030$).

Discussion

Noise-induced hearing loss is a common cause of hearing impairment throughout the world [1]. However, the level and duration of the sounds vary, and there are few well-organized reports apart from those dealing with AT due to firearms involving military personnel. AT and other types of ANIHL differ in terms of the level and duration of the source of sounds, and it might be appropriate to handle these conditions separately. To the best of our knowledge, there is no study comparing the hearing prognosis between AT and ANIHL for cases accumulated as part of a multi-institutional study.

In this systematic review, most of the articles described subjects exposed to firearms or military personnel, and most of the cases were regarded as AT because of the exposure to intense sounds from firearms and explosions. Systemic steroid therapy was the most frequently used; however, the treatment efficacy of systemic steroid therapy was reported not to be adequate in almost all of articles in this review. The severity of the cochlear damage due to AT might be one reason for the insufficient recovery in spite of steroid treatment.

Critical factors, such as the early initiation of treatment [7], were discussed in the previous articles. In our study, age and time from onset to treatment did not differ significantly between the AT and ANIHL groups. The initial hearing levels [8] were also similar in the two groups in this study. However, hearing recovery was significantly better in the ANIHL group than in the AT group. The sound source causing the ANIHL rather than the initial level of hearing loss appeared to be more important in predicting hearing recovery.

Steroids are the most widely applied agent for the treatment of acute hearing loss. As both AT and ANIHL involve acute hearing loss, most of the cases were treated with systemic steroid therapy. However, the efficacy of steroid therapy for ANIHL was not conclusive in this study, particularly as there were few cases not treated by steroid therapy (only three cases). The majority of the subjects in the reviewed articles dealing with this topic were AT cases, particularly military personnel, exposed to firearm noise. The available evidence on the effectiveness of steroids in the treatment of

ANIHL is quite limited. The efficacy of systemic steroid therapy might depend on the severity of the noise-induced cochlear damage.

Nevertheless, our review indicated that AT was generally unrecoverable, even with systemic steroid treatment. Therefore, other treatment strategies might be considered. It is possible that HBO can ameliorate the damage associated with AT [5]; however, the effects of HBO remain controversial [7]. There was no patient treated with HBO in this study, and further study on the effects HBO on AT is needed. Of course, protection of the ears against predictable loud sounds, such as gun-shots, is strongly recommended. Differential diagnosis of AT and ANIHL is also considered to be important as the latter has greater potential for recovery. Further study is needed to clarify the effects of steroids and other treatment modalities on ANIHL.

This study has several limitations. First, the study was neither prospective nor randomized. From an ethical standpoint, a completely randomized study on steroid treatment is difficult to perform. Second, in this study, gun-shots and explosions were differentiated from the other types of loud sounds; however, the distance from the sound source and the exact level of the sounds were unmeasurable. Third, our study population was quite small, despite the fact that they were accumulated through a multi-institutional survey. In future, a larger number of samples should be included in a more definitive study.

Conclusions

Among the AT cases resulting from exposure to firearms and explosions, systemic steroid therapy appeared to be generally ineffective. In contrast, among the ANIHL cases resulting from concert noise or other sources of loud sound, significant recovery in hearing was observed after treatment, with treatment in most cases including systemic steroid therapy. We emphasize the need to differentiate between these two types of ANIHL, AT or ANIHL, in terms of evaluating treatment efficacy and predicting hearing prognosis.

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Disclosure statement

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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